Plastics

Thoughts on Impedance Matching of Photos

To date we have talked about the possibility of a gradual shading of dielectric constant into and out of any structural element as a means of reducing the reflection from such a structural element in specified frequency bands.

This note is written in order to be more specific about some of the things that can be done in this direction. We shall take as our standard structural element for purposes of comparison, an 1/8" thick slab of dielectric with dielectric constant $k_o = 4$ (fiberglass laminate). For wave length long compared to the 1/8" thickness, the normal incidence power reflection coefficient is given by

$$R = \left[\frac{(\sqrt{k_o} - 1) 4\pi d}{(\sqrt{k_o} + 1) \lambda} \right]^2$$

This expression is plotted as a function of frequency in the range of interest in Figure 1. For the higher frequencies the exact expression rather than the approximate expression above is used.

If we now wish to reduce the reflection coefficient in a particular band we can do it by the well-known technique used in coating optical lenses. A quarter wave length thick layer is placed on the front and back surfaces; the index of this layer being the square root of the index of the slab to be protected. Figure 2 gives a free-hand sketch of the reflection coefficient from such a system as a function of frequency. This sketch is made through circled points which have been

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calculated. It is noticed in this case in which the design frequency is S-band, we have a harmonic resonance occurring in X-band when the protecting slab is $3/4 \lambda$ thick. Other minima occur at 15,000 MC, 21,000 MC, etc. but these get progressively narrower on a percentage basis.

A multistep taper may be used to improve this performance more. Figure 3 gives the result of a four-step taper in which the total thickness of the taper is the same as in Figure 2. The index of refraction of each section of the taper is the geometric mean of the adjacent sections. In this approach we have sacrificed some performance at S-band in favor of more bandwidth at X-band and improved performance in general between S-band and 18,000 MC. It will be noticed that the lowest frequency minimum has shifted up to 4500 MC. As a matter of fact as the number of steps in the transition is increased while holding the total thickness constant this frequency will continue to shift up. For a continuously varying transition, this frequency would be at 6000 MC for a one-inch transition.

In those structures in which sandwich construction is used another gambit becomes possible. If the skins of the sandwich are spaced by a quarter of a wave length, we have a return quite similar to that of Figure 2 except for an upward shift by 6 db if each skin remains 1/8" thick. If we further provide each surface associated associated with the skin with a $\lambda/4$ single layer taper effective at X-band, we can broaden the minimum at X-band by about a factor of three or we can provide an additional minimum in the vicinity of 6000 MC.

In my previous thinking I have assumed that these tapers would be costly in weight since I was thinking of a tapered form. However it should be possible to make artificial dielectrics by loading a light foam with flake aluminum. It should be quite simple to get dielectric constants as high as four by this technique. I have asked ▓▓▓▓ to load such a foam quite heavily to see what kind of dielectric constants we can get.

It probably will prove impractical to combine such highly transparent techniques with specular shaping for the plastics. The technique of getting a sharp edge in metal while having a rounded edge aerodynamically probably won't work in plastics since I would guess a sharp structural edge in plastic is not very practical. On the other hand if shading works as well as hoped, further improvement by specular shaping of plastic parts should not be required, for the major contribution to the cross section should now be from the engine and equipment bay which can be seen through the transparent fuselage and to some extent past the protective discs especially at higher frequencies.

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